650.01 General

It is essential that the driver of a vehicle be able to see far enough ahead to assess developing situations and take appropriate action. For purposes of design, the required sight distance is considered in terms of passing sight distance, stopping sight distance, and decision sight distance.

For additional information, see the following chapters:

Chapter	Subject
910	sight distance at intersections at grade
915	sight distance at roundabouts
920	sight distance at road approaches
930	sight distance at railroad crossings
1020	sight distance for paths and trails

650.02 References

Design Guidance Guidance included by reference within the text includes:

Manual on Uniform Traffic Control Devices for Streets and Highways, USDOT, FHWA; including the Washington State Modifications to the MUTCD, Chapter 468-95 WAC, (MUTCD) http://www.wsdot.wa.gov/biz/trafficoperations/mutcd.htm

Supporting Information Other resources used or referenced in this chapter includes:

A Policy on Geometric Design of Highways and Streets, AASHTO, 2001

650.03 Definitions

decision sight distance The distance required for a driver to detect an unexpected or difficult-to-perceive information source or hazard, interpret the information, recognize the hazard, select an appropriate maneuver, and complete it safely and efficiently.

design speed The speed used to determine the various geometric design features of the roadway.

passing sight distance The distance (on a two-lane highway) required for a vehicle to execute a normal passing maneuver based on design conditions and design speed.

roadside That area between the outside shoulder edge and the right of way limits. The median area between the edges the shoulders on a divided highway is also considered roadside.

roadway The portion of a highway, including shoulders, for vehicular use.

rural design area An area that meets none of the conditions to be an urban design area.

sight distance The length of highway visible to the driver.

stopping sight distance The distance required to safely stop a vehicle traveling at design speed.

suburban area A term for the area at the boundary of an urban area. Suburban settings may combine the higher speeds common in rural areas with activities that are more similar to urban settings.

urban area An area designated by WSDOT in cooperation with the Transportation Improvement Board and regional transportation planning organizations, subject to the approval of the FHWA.

urban design area An area where urban design criteria is appropriate, that is defined by one or more of the following:

- An urban area.
- An area within the limits of an incorporated city or town.

- An area characterized by intensive use of the land for the location of structures and receiving such urban services as sewer, water, and other public utilities and services normally associated with an incorporated city or town. This may include an urban growth area defined under the Growth Management Act (Chapter 36.70A RCW Growth management—planning by selected counties and cities), but outside the city limits.
- An area with not more than 25% undeveloped land.

650.04 Stopping Sight Distance

(1) Design Criteria

Stopping sight distance is the sum of two distances: the distance traveled during perception and reaction time and the distance required to stop the vehicle. The perception and reaction time used in design is 2.5 seconds. The stopping distance is calculated using a constant deceleration rate of 11.2 feet/second^2.

Provide design stopping sight distance (see Figure 650-1) at all points on all highways and on all intersecting roadways, except when evaluating an existing roadway, as provided in 650.04(7).

Available stopping sight distance is calculated for a passenger car using an eye height (h_1) of 3.50 feet and an object height (h_2) of 0.50 foot. Although AASHTO allows a 2-foot object height, a 0.5-foot object height is used because objects with a height between 0.5 foot and 2 feet may be perceived as hazards that would likely result in an erratic maneuver. In urban design areas, with justification, the object height (h_2) may be increased to 2.00 feet. Figure 650-1 gives the design stopping sight distances for grades less than 3%, the minimum curve length for a 1% grade change to provide the sight distance (using h_2=0.50 feet) for a crest (K_C) and sag (K_S) vertical curve, and the minimum length of vertical curve for the design speed (VCL_m). (See 650.04(2) for sight distances when the grade is 3% or greater.)

Design Speed (mph)	Design Stopping Sight Distance (ft)	K_C	K_S	VCL_m (ft)
25	155	18	25	75
30	200	30	36	90
35	250	47	49	105
40	305	70	63	120
45	360	98	78	135
50	425	136	96	150
55	495	184	115	165
60	570	244	136	180
65	645	313	157	195
70	730	401	180	210
75	820	506	206	225
80	910	623	231	240

Design Stopping Sight Distance
Figure 650-1

(2) Effects of Grade

The grade of the highway has an effect on the vehicle's stopping sight distance. The stopping distance is increased on downgrades and decreased on upgrades. Figure 650-2 gives the stopping sight distances for grades of 3% and steeper. When evaluating sight distance with a changing grade, use the grade for which the longest sight distance is needed.

Design Speed (mph)	Stopping Sight Distance (ft)					
	Downgrade			Upgrade		
	-3%	-6%	-9%	3%	6%	9%
25	158	165	173	147	143	140
30	205	215	227	190	184	179
35	258	271	288	237	229	222
40	315	333	354	289	278	269
45	378	401	428	345	331	320
50	447	474	508	405	389	375
55	520	553	594	470	450	433
60	599	638	687	539	515	495
65	683	729	786	612	585	561
70	772	826	892	690	658	631
75	867	928	1004	773	736	705
80	966	1037	1123	860	818	782

Design Stopping Sight Distance on Grades
Figure 650-2

For stopping sight distances on grades between those listed, interpolate between the values given or use the equation in Figure 650-3.

$$S = 1.47Vt + \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) \pm \frac{G}{100}\right]}$$

Where:
S = Stopping sight distance on grade (ft)
V = Design speed (mph)
t = Perception/reaction time (2.5 sec)
a = Deceleration rate (11.2 ft/sec^2)
G = Grade (%)

Stopping Sight Distance on Grades
Figure 650-3

(3) Crest Vertical Curves

Use Figure 650-11 or the equations in Figure 650-4 to find the minimum crest vertical curve length to provide stopping sight distance when given the algebraic difference in grades. When using the equations in Figure 650-4, use h_1=3.50 feet and h_2=0.50 foot. Figure 650-11 does not use the sight distance greater than the length of curve equation. When the sight distance is greater than the length of curve and the length of curve is critical, the S>L equation given in Figure 650-4 may be used to find the minimum curve length.

When a new crest vertical curve is built or an existing one is rebuilt with grades less than 3%, provide Design Stopping Sight Distance from Figure 650-1. When grades are 3% or greater, see 650.04(2) for required sight distance.

In urban design areas, with justification, an object height (h_2) of 2.00 feet may be used with the equations in Figure 650-4.

When evaluating an existing roadway, see 650.04(7).

When S>L

$$L = 2S - \frac{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2}{A} \qquad S = \frac{L}{2} + \frac{100\left(\sqrt{h_1} + \sqrt{h_2}\right)^2}{A}$$

When S<L

$$L = \frac{AS^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \qquad S = \sqrt{\frac{200L\left(\sqrt{h_1} + \sqrt{h_2}\right)^2}{A}}$$

Where:
L = Length of vertical curve (ft)
S = Sight distance (ft)
A = Algebraic difference in grades (%)
h_1 = Eye height (3.50 ft)
h_2 = Object height—*see text* (ft)

Sight Distance, Crest Vertical Curve
Figure 650-4

(4) Sag Vertical Curves

Sag vertical curves are only a sight restriction during the hours of darkness. Headlight sight distance is used for the sight distance design criteria at sag vertical curves. In some cases, a lesser length may be allowed. (See Chapter 630 for guidance and requirements.)

Use Figure 650-12 or the equations in Figure 650-5 to find the minimum length for a sag vertical curve to provide the headlight stopping sight distance when given the algebraic difference in grades. The sight distance greater than the length of curve equation is not used in Figure 650-12. When the sight distance is greater than the length of curve and the length of curve is critical, the S>L equation given in Figure 650-5 may be used to find the minimum length of curve.

When a new sag vertical curve is built or an existing one is rebuilt with grades less than 3%, provide Design Stopping Sight Distance from Figure 650-1. When grades are 3% or greater, see 650.04(2) for required sight distance.

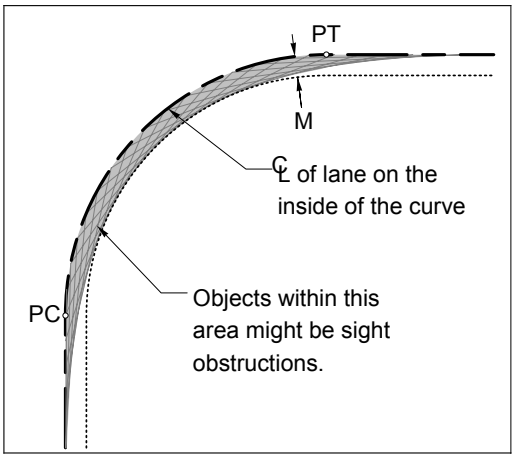
When evaluating an existing roadway, see 650.04(7).

Where S>L	
$L = 2S - \frac{400 + 3.5S}{A}$	$S = \frac{LA + 400}{2A - 3.5}$
Where S<L	
$L = \frac{AS^2}{400 + 3.5S}$	$S = \frac{3.5L \pm \sqrt{(3.5L)^2 + 1600AL}}{2A}$
Where: L = Curve length (ft) A = Algebraic grade difference (%) S = Sight distance (ft)	

Sight Distance, Sag Vertical Curve
Figure 650-5

(5) Horizontal Curves

Use Figure 650-13a or the equation in Figure 650-7 to check for adequate stopping sight distance where sight obstructions are on the inside of a curve. A stopping sight distance obstruction is any roadside object within the M distance (such as median barrier, guardrail, bridges, walls, cut slopes, wooded areas, and buildings), 2 feet or greater above the roadway surface at the centerline of the lane on the inside of the curve. Figure 650-13a and the equation in Figure 650-7 are for use when the length of curve is greater than the sight distance and the sight restriction is more than half the sight distance from the end of the curve. When the length of curve is less than the stopping sight distance or the sight restriction is near either end of the curve, the desired sight distance may be available with a lesser M distance. (See Figure 650-6.) When this occurs, the sight distance can be checked graphically.



Sight Distance Area on Horizontal Curves
Figure 650-6

When the road grade is less than 3%, provide Design Stopping Sight Distance from Figure 650-1.

When the grade is 3% or greater, see 650.04(2) for required sight distance.

In urban design areas, with justification, a 2.00-foot object height (h_2) may be used. When h_2=2.00 feet, roadside objects between 2.00 feet and 2.75 feet might not be a sight obstruction. (See Figure 650-13b for guidance on determining whether a roadside object is a sight obstruction.)

When evaluating an existing roadway, see 650.04(7).

$M = R\left[1 - \cos\left(\frac{28.65\,S}{R}\right)\right]$	
$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R - M}{R}\right)\right]$	
Where: M = Distance from the centerline of the inside lane of the curve to the sight obstruction (ft) R = Radius of the curve (ft) S = Sight distance (ft)	

Sight Distance, Horizontal Curves
Figure 650-7

(6) Overlapping Horizontal and Vertical Curves

A vertical curve will affect the height at which a roadside object will become a sight obstruction. A crest vertical curve will raise roadside objects and make them more likely to become sight obstructions. A sag vertical curve will lower roadside objects, making them less likely to be sight obstructions.

(7) Existing Stopping Sight Distance

Existing stopping sight distance is used when the vertical and horizontal alignments are unchanged, the sight obstruction is existing, and there are no problems related to the sight distance. Figure 650-8 gives the values for existing stopping sight distance and the associated K_C and K_S. When evaluating the existing sight distance, use an object height (h_2) of 2.00 feet.

For crest vertical curves where the existing vertical alignment is retained and the existing roadway pavement is not reconstructed, existing stopping sight distance values in Figure 650-8 may be used. The minimum length of an existing crest vertical curve may be found using the equations in Figure 650-4 and h_2=2.00 feet, or using the K_C values from Figure 650-8.

For sag vertical curves where the existing vertical alignment is retained and the existing roadway pavement is not being reconstructed, existing stopping sight distance values in Figure 650-8 may be used. The minimum length of an existing sag vertical curve may be found using the equations in Figure 650-5, or using the K_S values from Figure 650-8. In some cases, when continuous illumination is provided, a lesser length may be allowed. (See Chapter 630 for guidance.)

For horizontal curves, existing stopping sight distance values from Figure 650-8 may be used when all of the following are met at the curve:

- The vertical and horizontal alignments are existing
- The roadway pavement will not be reconstructed
- The roadway will not be widened
- The sight obstruction is existing
- Roadside improvements to sight distance do not require additional right of way`

A sight obstruction is any roadside object within the M distance from the equation in Figure 650-7 with a height more than 2.75 feet above the centerline of the inside lane. Roadside objects between 2.00 feet and 2.75 feet might be a sight obstruction. (See Figure 650-13b for guidance on determining whether a roadside object is a sight obstruction.)

Design Speed (mph)	Existing Stopping Sight Distance (ft)	K_C	K_S
20	115	6	16
25	145	10	23
30	180	15	31
35	220	22	41
40	260	31	52
45	305	43	63
50	350	57	75
55	400	74	89
60	455	96	104
65	495	114	115
70	540	135	127
75	585	159	140
80	630	184	152

Existing Stopping Sight Distance
Figure 650-8

650.05 Passing Sight Distance

(1) Design Criteria

Passing sight distance is the sum of four distances:

- The distance traveled by the passing vehicle during perception and reaction time and initial acceleration to the point of encroachment on the opposing lane.
- The distance the passing vehicle travels in the opposing lane.
- The distance that an opposing vehicle travels during two-thirds of the time the passing vehicle is in the opposing lane.
- A clearance distance between the passing vehicle and the opposing vehicle at the end of the passing maneuver.

Sight distance for passing is calculated for a passenger car using an eye height (h_1) of 3.50 feet and an object height (h_2) of 3.50 feet. Figure 650-9 gives the passing sight distances for various design speeds.

Design Speed (mph)	Passing Sight Distance (ft)
20	710
25	900
30	1090
35	1280
40	1470
45	1625
50	1835
55	1985
60	2135
65	2285
70	2480
75	2580
80	2680

Passing Sight Distance
Figure 650-9

On two-lane two-way highways, provide passing opportunities to meet traffic volume demands. This can be accomplished by using numerous sections with safe passing sight distance or by adding passing lanes at critical locations. (See Chapter 1010.)

In the design stage, passing sight distance can be provided by adjusting the alignment either vertically or horizontally to increase passing opportunities.

These considerations also apply to multilane highways where staged construction includes a two-lane two-way operation as an initial stage. Whether auxiliary lanes are provided, however, depends on the time lag proposed between the initial stage and the final stage of construction.

(2) Vertical Curves

Figure 650-14 gives the length of crest vertical curve needed to provide passing sight distance for two-lane highways. The distance from Figure 650-9 and the equations in Figure 650-4, using 3.50 feet for both h_1 and h_2, may also be used to determine the minimum length of vertical curve to provide the required passing sight distance.

Sag vertical curves are not a restriction to passing sight distance.

(3) Horizontal Curves

Passing sight distance can be restricted on the inside of a horizontal curve by roadside objects that are 3.50 feet or more above the roadway surface. Use the distance from Figure 650-9 and the equation in Figure 650-7 to determine whether the object is close enough to the roadway to be a restriction to passing sight distance. The equation assumes that the curve length is greater than the sight distance. Where the curve length is less than the sight distance, the desired sight distance may be available with a lesser M distance.

(4) No-Passing Zone Markings

Knowledge of the practices used for marking no-passing zones on two-lane roads is helpful in designing a safe highway. The values in Figure 650-9 are the passing sight distances starting at the point the pass begins. The values in the MUTCD are lower than the Figure 650-9 values. They are for no-passing zone marking limits and start at the point the safe pass must be completed.

The MUTCD values are not to be used directly in design, but are discussed for the designer's recognition of locations requiring no-passing pavement markings. Sections of highway providing passing sight distance in the range of values between the distances in Figure 650-9 and MUTCD values require careful review by the designer.

650.06 Decision Sight Distance

Decision sight distance values are greater than stopping sight distance values because they give the driver an additional margin for error and afford sufficient length to maneuver at the same or reduced speed rather than to just stop.

Provide decision sight distance where highway features create the likelihood for error in information reception, decision making, or control actions. Example highway features include interchanges; intersections; changes in cross section (such as at toll plazas and drop lanes); and areas of concentrated demand where sources of information compete (for example, those from roadway elements, traffic, traffic control devices, and advertising signs). If possible, locate these highway features where decision sight distance can be provided. If this is not possible, use suitable traffic control devices and positive guidance to give advanced warning of the conditions.

Use the decision sight distances in Figure 650-10 where highway features require complex driving decisions.

Design Speed (mph)	Decision Sight Distance for Maneuvers (ft)				
	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545
80	970	1685	1260	1455	1650

Decision Sight Distance
Figure 650-10

The maneuvers in Figure 650-10 are as follows:

A. Rural stop

B. Urban stop

C. Rural speed/path/direction change

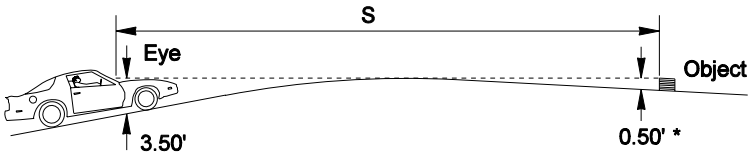
D. Suburban speed/path/direction change

E. Urban speed/path/direction change

Decision sight distance is calculated using the same criteria as stopping sight distance: h_1=3.50 feet and h_2=0.50 foot. Use the equations in Figures 650-4, 5, and 7 to determine the decision sight distance for crest vertical curves, sag vertical curves, and horizontal curves.

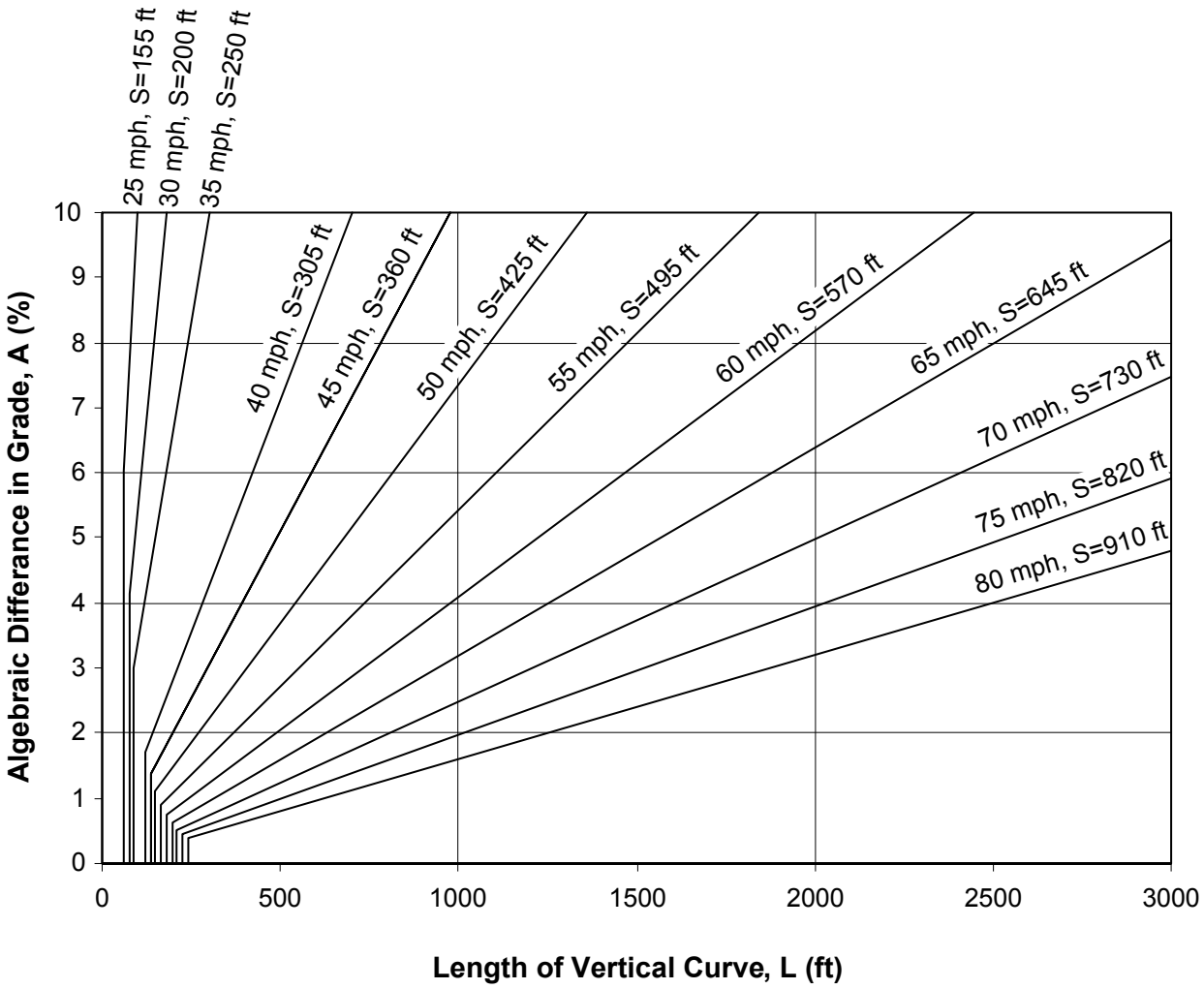
650.07 Documentation

The list of documents that are to be preserved in the Design Documentation Package (DDP) or the Project File (PF) can be found on the following web site:
http://www.wsdot.wa.gov/eesc/design/projectdev/

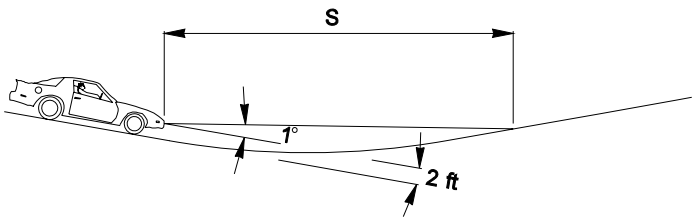


The minimum length can also be determined by multiplying the algebraic difference in grades by the K_C value from Figure 650-1 ($L=K_C*A$). Both the figure and the equation give approximately the same length of curve. Neither use the S>L equation.

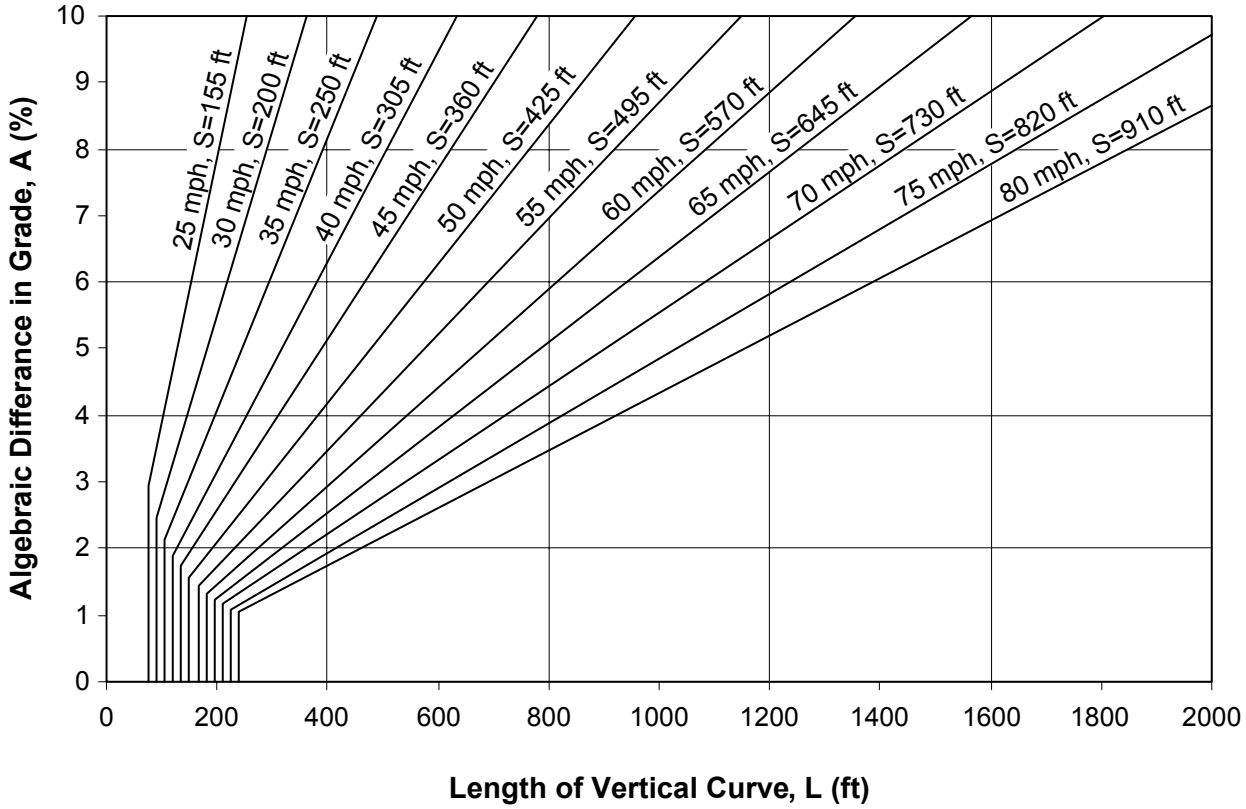
* This chart is based on a 0.50-foot object height. When a higher object height is allowed (see 650.04(3) for guidance), the equations in Figure 650-4 must be used.



Stopping Sight Distance for Crest Vertical Curves
Figure 650-11

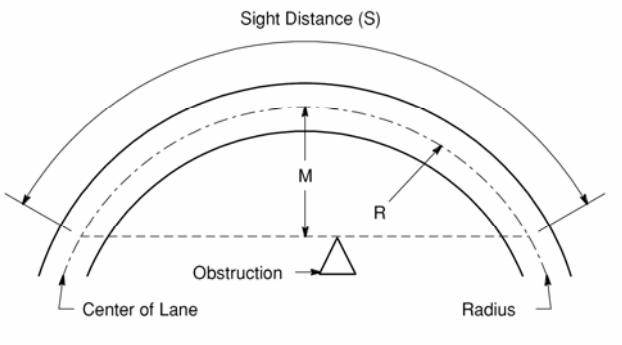


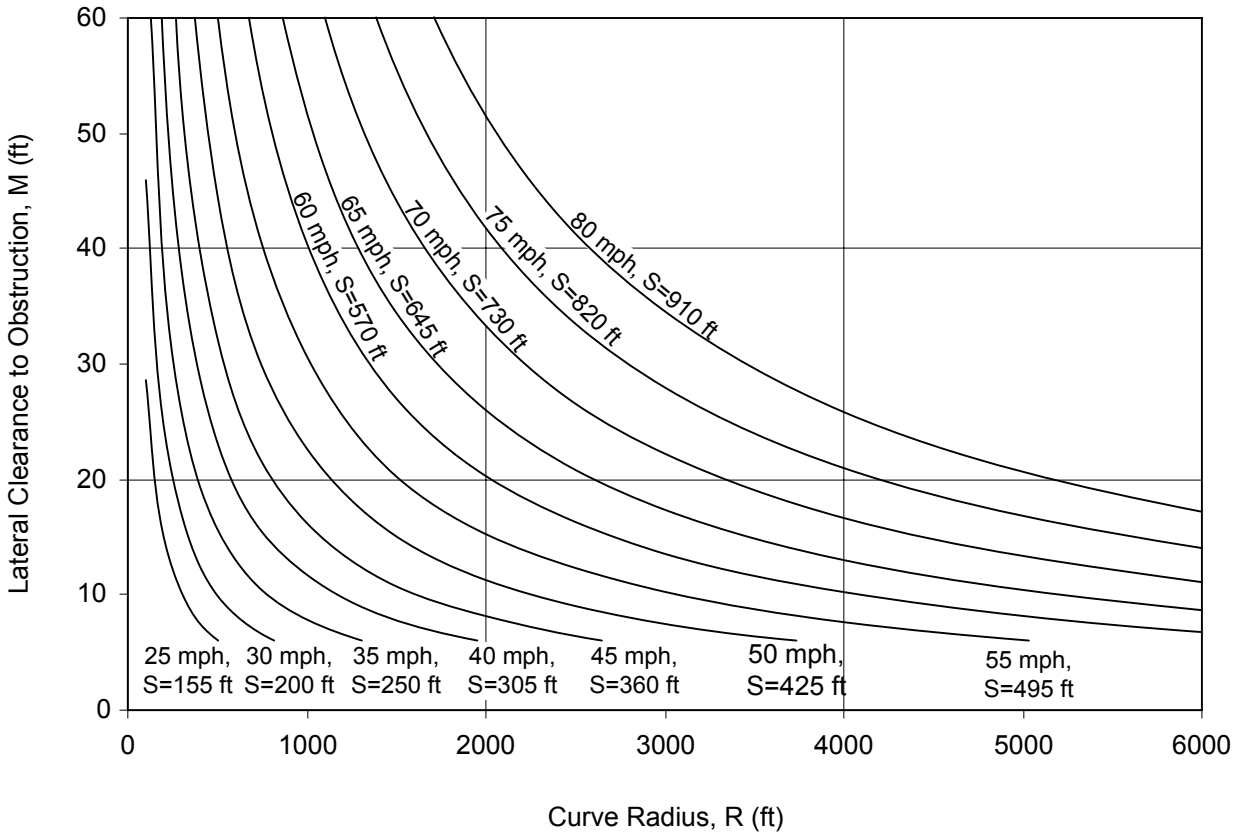
The minimum length can also be determined by multiplying the algebraic difference in grades by the K_S value from Figure 650-1 ($L=K_S*A$). Both the figure and equation give approximately the same length of curve. Neither use the S>L equation.



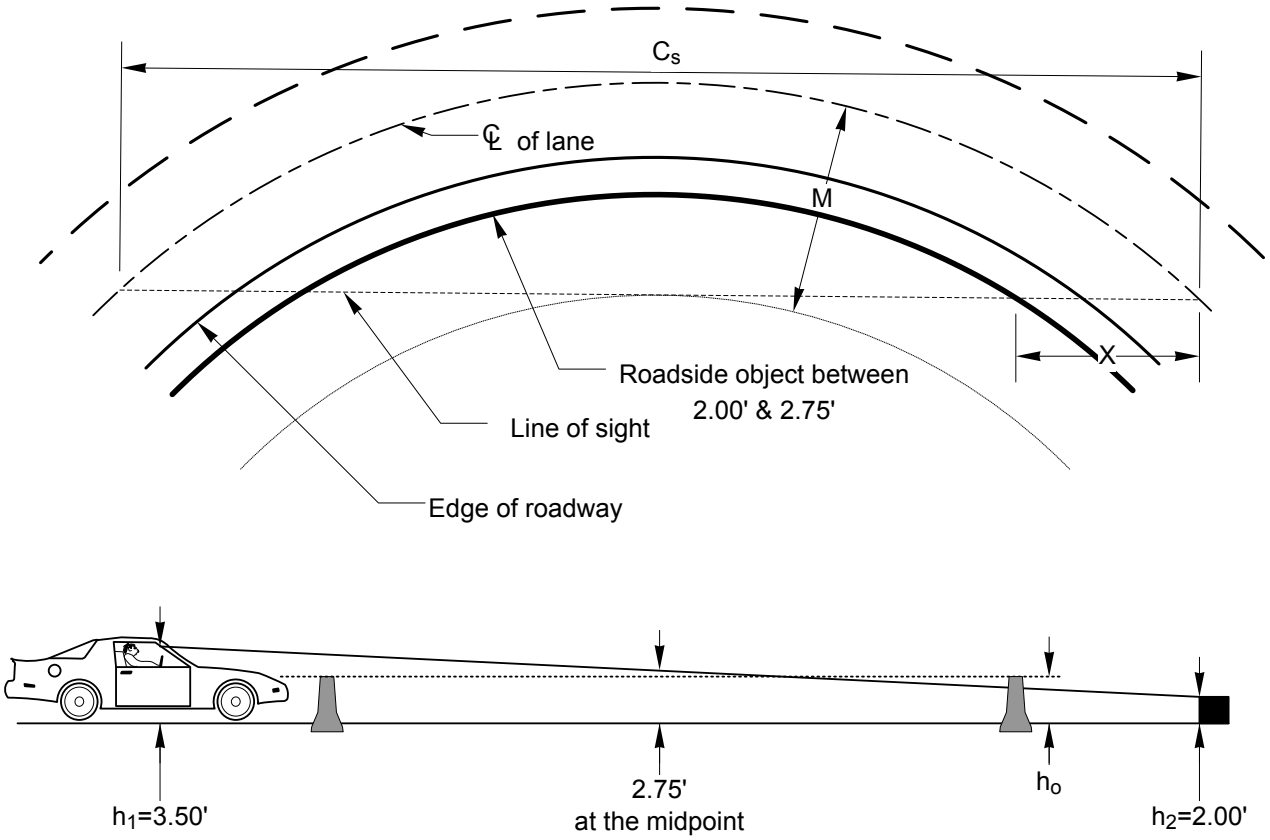
Stopping Sight Distance for Sag Vertical Curves
Figure 650-12

When h_2=2.00 ft, objects between 2.00 ft and 2.75 ft above the centerline of the inside lane might be a sight obstruction. (See Figure 650-13b for guidance.)





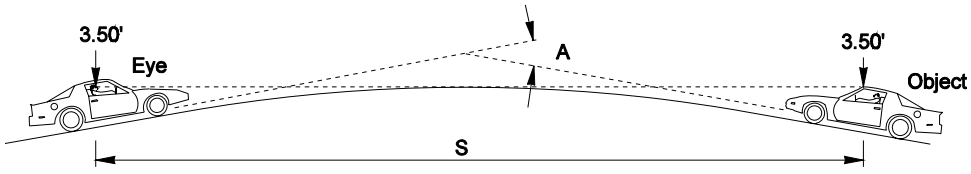
Horizontal Stopping Sight Distance
Figure 650-13a



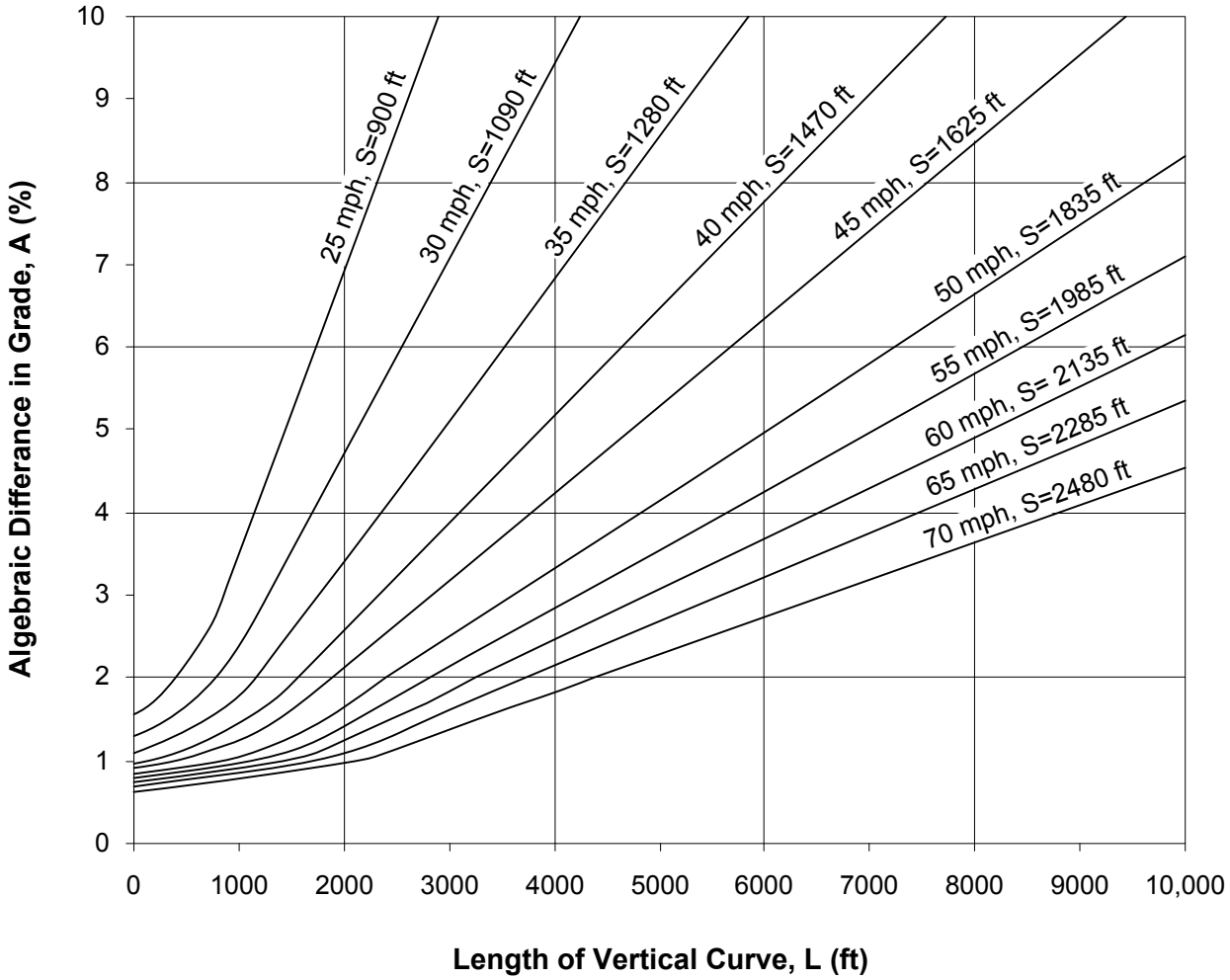
When $h_o > \left(2 + \frac{0.75X}{½C_s}\right)$, roadside object is a sight obstruction.

Where:
M = Lateral clearance for sight distance (feet) (see Figure 650-7)
C_S = Stopping sight distance chord (feet)
X = Distance from the sight obstruction to the end of the sight distance chord (feet)
h_o = Height of roadside object above the centerline of the inside lane (feet)

Horizontal Stopping Sight Distance
Figure 650-13b



Where S>L	
$L = 2S - \frac{2800}{A}$	$S = \frac{L}{2} + \frac{1400}{A}$
Where S<L	
$L = \frac{AS^2}{2800}$	$S = \sqrt{\frac{2800L}{A}}$
L = Curve length (ft) A = Algebraic grade difference (percent) S = Sight distance (ft)	



Passing Sight Distance for Crest Vertical Curves
Figure 650-14